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Instruction Manual for

PRECISION DIFFERENTIAL VOLTMETER
/D.C.SUPPLY
TYPE VR2

MP MASTER
MA23389

FARNELL INSTRUMENTS LIMITED
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FARNELL INSTRUMENTS LIMITED

INSTRUCTION

MANUAL

FOR

PRECISION DIFFERENTIAL VOLTMETER
/D.C.SUPPLY
TYPE VR2

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Section 1. INTRODUCTION

The Precision Differential Voltmeter /D.C. Supply, Type VR2 is a dual purpose laboratory instrument combining the functions of a stabilised reference voltage supply and a differential voltmeter.

As a stabilised reference supply the VR2 is outstanding in that it is capable of supplying load currents up to 500mA while maintaining the selected supply voltage in the range 0 to 100V with an accuracy of ±0.03% of the selected voltage ±2mV in spite of wide variations in mains voltage, load current and temperature.

As a differential voltmeter, the VR2 offers the advantages of a null reading instrument - while also offering the facility of a direct meter indication - for measurement of unknown D.C. voltages in the range 0 to 1,000V.

The VR2 is A.C. mains powered and is adjustable for 50-60 c.p.s. supply voltages in the ranges 90 - 130V and 200 - 240V.

The instrument is housed in a metal case from which it may be readily removed for rack mounting on a 19" standard rack.

Easily read scales and clearly marked controls ensure speed and ease of use of the instrument. Reliability and long life are ensured by care in design, choice of suitable solid state components - including silicon transistors - and rugged construction.

Section 2. SPECIFICATION

Power Requirements:	50 - 60 c.p.s. A.C.; 100 watts 110 ±5, ±10, ±20V. nominal, or 220 ±5, ±10, ±20V. nominal; ±7½% variation in nominal supply voltage is allowable.
Input Fuse:	anti-surge; 2A for 110V supply range, 1A for 220V supply range.
Dimensions:	Cased Unit: 20" x 10" x 10½" (508mm x 254mm x 267mm). Rack Unit: 19" standard rack mounting, panel height - 7" (178mm), projection behind panel - 10" (254mm).
Weight:	Approximately 20 pounds (9Kg.)
Finish:	Blue hammer - finish case with dove-grey enamelled front panel.
Ambient Operating Temperature Range:	10°C to 35°C (50°F to 95°F.)

Precision Voltage Reference Supply Section

Output Voltage:	00.000 to 100.000V selected by five decade switches.
Output Current	0 to 500mA, monitored.
Output Fuse:	1A.
Setting Accuracy:	Within 0.02% of set reading ±1mV at 20°C ambient temperature and under no load conditions.
Line Regulation:	Less than 0.005% of output voltage ±1mV for ±7½% change in supply voltage.
Load Regulation:	Less than 0.005% of output voltage ±2mV for 0 to 500mA change in load current.

Temperature Effect:	Less than 0.01% of output voltage from 10°C to 35°C relative to output at 20°C.
Overall Accuracy:	±0.03% of setting ±2mV including all effects quoted above.
Zero Accuracy:	Better than 0.1mV.
Output Ripple Voltage:	Less than 1mV peak to peak.
Overload Protection:	Current limiting and reducing circuit, operating at 600mA output current and reducing short circuit output current to 150mA. Automatic reset on removal of overload.

Differential Voltmeter Section

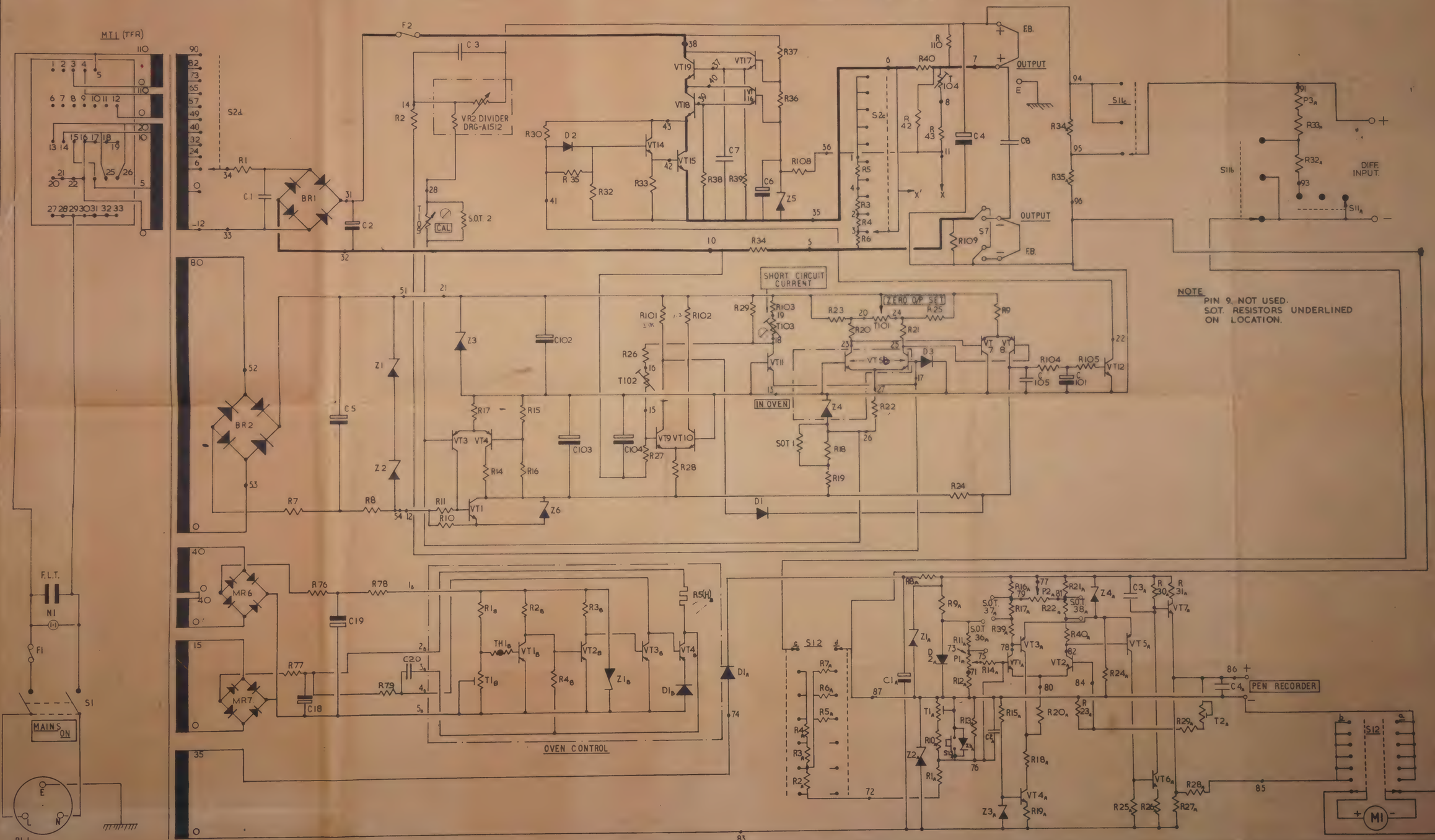
Range:	0 to 1,000V, with x 0.1, x 1 and x 10 multiplier.
Differential Sensitivity:	100, 10, 1.0, 0.1, 0.01 and 0.001 volts for F.S.D. selected by six position switch.
Accuracy	
On meter indication	±3% of Full Scale Deflection.
On null indication	±.05% of measured voltage ±2mV on x 0.1 multiplier position.
	±.03% of measured voltage ±2mV (supply accuracy) on x 1 multiplier position.
	±0.2% of measured voltage on x 10 multiplier position.

DRAWING No
C1500

THIRD ANGLE PROJECTION

USED ON 1500

R.	
C.	
T. & P.	
MISC.	PL1 FLT MT1 BR2 S2d BR1 Z1 Z3 Z6 D2 Z1B D1B D1A D1 Z5 Z4 Z1B Z2A D2A Z5A Z3B Z4A S11c S11b S12
MISC.	F1 S1 N1 BR3 BR4 Z2 F2 S12 S2c D3 S13 S11a M1



NOTE.
PIN 9. NOT USED.
S.O.T. RESISTORS UNDERLINED ON LOCATION.

TRACED						TOLERANCES	PROTECTIVE FINISH
CHECKED						MATERIAL	
DRAWN	ISSUE	DATE	MOD. No.				DIMENSIONS IN
	1	25:10:66.					

FARNELL INSTRUMENTS LTD., WETHERBY, YORKS.

TITLE
CIRCUIT DIAGRAM — V R 2

DRAWING No.
C1500

SHEET 1 OF 1 SHEETS

Input Resistance	Infinite on x 0.1 and x 1 multiplier positions.	
At null:	10 Megohms on x 10 multiplier position.	
At F.S.D.	1mV range	100 Megohms per volt
	10mV range	100 Megohms per volt
	100mV range	100 Megohms per volt
	1 V range	10 Megohms per volt
	10 V range	1 Megohm per volt
	100 V range	100 Kilohms per volt

Section 3.

THEORY OF OPERATION - CIRCUIT DESCRIPTION

The mains input is fed into the primary of the transformer MT1 via switch S1 and fuse F1. The capacitor FLT1 functions as a mains input filter.

D.C. SUPPLY SECTION. (Refer to Drawing No. C1500)

A switched secondary winding of MT1 feeds the bridge rectifier BR1 comprising silicon diodes whose output feeds the reservoir capacitor C2 to provide the main unstabilised D.C. supply. The positive of this supply is fed via the fuse F2 and the series regulator control elements VT19, VT18 and VT15 to the positive output terminal and the negative of this supply is connected to the negative terminal. R40 and R34 in these positive and negative output leads are current sensing resistors for current monitoring on the built in meter and for short-circuit protection purposes respectively.

A second secondary winding of MT1 feeds the bridge rectifier BR2 comprising silicon diodes whose output feeds the reservoir capacitor C5 to provide the auxiliary unstabilised D.C. supply for the reference zener diode and D.C. control amplifier. This supply is stabilised by the zener regulator stage comprising Z1, Z2 and R8. Further stabilisation for the D.C. control amplifier comprising VT5, VT6, VT7 and VT8 is given by Z3 which provides a 7 volt positive supply relative to the negative feedback terminal.

Further stabilisation for the reference zener diode, Z4, is achieved by means of the series control element VT1 controlled by the differential amplifier VT3 and VT4 using the reference zener diode Z4 itself as reference. The collector of VT1 provides a 20 volt negative supply relative to the negative feedback terminal, which feeds current to Z4 via the high stability resistors R18 and R19. This method of deriving the current for the reference zener diode stabilises the reference voltage against supply variations and ensures that the reference zener current is maintained at a level corresponding to a temperature coefficient of the reference voltage of less than 0.001% per $^{\circ}$C.

The positive side of the reference zener diode, Z4, is connected to the negative feedback terminal and to the base of VT5.

A resistive divider network is connected between the positive feedback terminal and the negative side of the reference zener diode. The output of the divider network - which is an appropriate fraction of the output voltage plus the reference voltage as determined by the setting of the output control decade switches - is applied via R2 to the base of VT6. The main portion of the resistive divider is made up of precision resistors, with temperature coefficients matched to within 5 parts per million per $^{\circ}$C, encapsulated so as to maintain each resistor at the same temperature and isolate them from the

effects of air currents or draughts.

The action of the control amplifier is to control the output voltage in such a manner as to maintain zero potential difference between the bases of VT5 and VT6, or in other words, to maintain the output voltage at the multiple of the reference voltage selected by means of the output control decade switches.

Any difference in voltage between the bases of VT5 and VT6 is amplified and applied to the bases of VT7 and VT8 where it is further amplified. The amplified signal is fed via a low-pass filter to the emitter follower VT14 which controls the series regulator VT15 in such a manner as to compensate for the original difference in the base potentials of VT5 and VT6.

VT5 and VT6 constitute a dual transistor comprising two low leakage silicon transistors - closely matched for base - to - emitter voltage and for temperature coefficient of base - to - emitter voltage - and mounted within one can to minimize temperature differentials. To further improve the temperature stability of the instrument, the differential amplifier dual transistor, VT5 and VT6 and the reference zener diode, Z4, are housed within a temperature controlled oven whose temperature is maintained at 50°C -0.5°C.

D3 provides a discharge path for the output capacitor C4 when the output controls are reset to a lower value, thus providing base - emitter protection for VT6 and preventing application of a positive voltage to the negative end of the reference zener diode, Z4, which would cause the reference zener current control circuit to "lock up".

R109 and R110 maintain a measure of feedback when the links or remote sensing leads are disconnected from the output or feedback terminals, to prevent complete loss of control action.

To prevent over-dissipation within the VR2 and to protect the equipment being supplied from it in case of overload, an overload protection circuit is fitted. This protection circuit limits the maximum current which can be drawn from the unit to 600mA and in the case of excessive overload progressively reduces this maximum to a value of 150mA under short-circuited load conditions.

VT9 is normally fully conducting - holding diode D1 in its non-conducting state, and VT10 and VT11 are non-conducting. When the output current approaches the chosen limiting value, the voltage generated across the sensing resistor R34 causes the voltage at the base of VT9 to go less positive taking VT9 out of saturation and turning on D1. This causes the current limiting circuitry to override the stabilising circuitry VT9 effecting control of VT12. The action of VT9 and VT10 is then to

stabilise the output current to a value proportional to the voltage across R26 and T102, keeping the output current constant until with increasing overload the output voltage reduces. This causes the bottom end feedback resistor of the precision divider network (RL13 and RL14 etc.) to draw current through VT11 in proportion to the reduction in output voltage, which in turn reduces the voltage across R26 and T102 thus causing the output current to be reduced to a safe low value.

VT18 and VT19 and the associated emitter followers VT16 and VT17 constitute pre-regulator stages. Normally Z5 conducts and VT18 and VT19 share the difference in voltage between the zener voltage of Z5 and the line to output voltage difference. On short circuit the series transistors VT15, VT18 and VT19 share the whole line voltage.

OVEN CONTROL SECTION (Refer to Drawing No. C1500).

The oven temperature controller consists of a four stage directly coupled amplifier comprising $VT1_B$, $VT2_B$, $VT3_B$ and $VT4_B$ driving the heating coil $R5_B$ which is wound around the oven enclosure. The input current to the base of $VT1_B$ is controlled by the thermistor $TH1_B$ which is mounted - together with the amplifier - within the oven enclosure. Any change in temperature in the oven enclosure causes a change in thermistor resistance and hence a change in the base current of $VT1_B$. This current change is amplified by $VT1_B$, $VT2_B$, $VT3_B$ and $VT4_B$ and fed to the heating coil $R5_B$ in such a sense as to oppose the original change in temperature.

$R4_B$ controls the open loop gain of the amplifier in order to prevent oscillation of the system.

$T1_B$ is used to set the absolute temperature of the oven enclosure.

Secondary windings on transformer MT1 feed the bridge rectifiers MR6 and MR7 comprising silicon diodes whose outputs are filtered to provide the temperature control heater and amplifier supplies, the amplifier supply being regulated by R78, $Z1_B$.

DIFFERENTIAL VOLTMETER SECTION (Refer to Drawing No. C1500).

The differential voltmeter consists of a switched multiplier, a switched input attenuator, a differential d.c. amplifier and associated power supply.

The multiplier comprising a three position switch S11, and resistors R32A, R33A, R34A, R35A and T3A, attenuates the reference voltage by a factor of 10 when in the "x 0.1" position, attenuates the voltage to be measured by a factor of 10 when in the "x 10" position, or provides no attenuation of either voltage when in the "x 1" position. The output from the multiplier applied to the input attenuator is therefore as follows:

for the "x 0.1" multiplier position - the difference between the voltage to be measured and 0.1 x the reference voltage;
for the "x 1" multiplier position - the difference between the voltage to be measured and the reference voltage;
for the "x 10" multiplier position - the difference between 0.1 x the voltage to be measured and the reference voltage.

The differential input signal is fed into the switched sections of the input attenuator comprising R2A to R7A and the preset sections of the input attenuator comprising the 2:1 attenuator R1A, R10A, R13A and T1A. The output of the attenuator for an input corresponding to full scale deflection is 0.5mV at the base of VT1A relative to the common line connected to pin 87.

The action of the differential amplifier is to produce an output voltage in such a manner as to maintain zero potential difference between the bases of VT1A and VT2A. Any difference in voltage between the bases of VT1A and VT2A is amplified and applied to the bases of VT3A and VT5A where it is further amplified. The amplified signal is fed to the base of VT6A whose collector output is fed to the emitter follower VT7A whose output is taken to the pen recorder output terminals and via a series resistor to the panel meter. The output of VT7A is also fed via the feedback attenuator comprising R23A, R29A and T2A to the base of VT2A in such a manner as to compensate for the original difference in the base potentials of VT1A and VT2A. The feedback attenuator ratio thus determines the gain of the differential amplifier - nominally 2,000 (i.e. a change of 0.5mV in the base potential of VT1A produces a change of 1V in the emitter potential of VT7A).

VT1A and VT2A constitute a dual transistor comprising two low leakage silicon transistors - closely matched for base - to - emitter voltage and for temperature coefficient of base - to - emitter voltage - housed within the temperature controlled oven to ensure temperature stability.

A secondary winding on transformer MT1 feeds the silicon rectifier D1A whose output is filtered by C1A and stabilised by the zener regulator stage comprising Z1A, Z2A and R8A to provide a positive and a negative 10 volt supply relative to the common line connected to pin 87. Z3A, VT4A and associated components provide a constant current source for VT1A and VT2A. R9A and D2A provide the voltage source for the open circuit zero adjustment R11A, P1A, R12A and R14A which feed a small potential to the base of VT1A.

The short circuit zero potentiometer P2A adjusts the collector loads of VT1A and VT2A.

The meter M1 is a 100 - 0 - 100uA movement whose sensitivity is determined by

R28A. On the switch position shown in the circuit diagram, the meter reads the output current of the D.C. Supply Section.

R28A. On the switch position shown in the circuit diagram, the meter reads the output current of the D.C. Supply Section.

Section 4. OPERATING INSTRUCTIONS

INSTALLATION

The instrument is fitted with a three pole chassis - mounted mains connector and supplied with a matching free connector. A three-core mains lead is fitted to the free connector and is colour coded:

Red	-	Live
Black	-	Neutral
Green	-	Earth

Before switching on, check the input voltage selector panel at the rear of the instrument and if necessary, adjust to match the supply voltage being used.

INSTRUMENT CONTROLS

MAINS (S1)
Toggle Switch

Supply voltage on-off switch. Presence of supply voltage is indicated by a neon indicator above S1.

OUTPUT (S7)
Toggle Switch

Output on-off switch. When S7 is on the output voltage is applied to the OUTPUT terminals. With S7 off, the instrument may be held in a "stand-by" condition thus eliminating the "warm-up" period when the output voltage is again required at the OUTPUT terminals.

OUTPUT
Terminals

Provide connection to the output voltage:

Red	-	Positive
Black	-	Negative
Green	-	Earth (chassis)

The supply may be operated in a fully floating condition.

FEEDBACK
Terminals

These are normally connected to the OUTPUT terminals by means of the links provided:

Red	-	Positive
Black	-	Negative

When it is required to compensate for voltage drop in the feed wires to a remote load, the links should

be removed and a separate pair of wires run from the FEEDBACK terminals to the remote load. It should be noted however, that since the current taken by the feedback circuit is 10mA, each 0.1 ohm of resistance in the feedback wires will cause 1mV error in the output voltage applied to the remote load.

OUTPUT CONTROLS
Five Rotary Switches

Output voltage setting controls. Reading from left to right, the dial figure superimposed on the coloured section of the front panel gives a digital indication of Tens of volts, volts, Hundreds of millivolts, Tens of millivolts and millivolts present at the FEEDBACK terminals. The first four are nine position rotary switches while the fifth is a ten position switch allowing an output of 100.00 volts to be obtained with dial settings of 9, 9, 9, 9, 10.

RANGE SELECTOR
7 - position
Rotary Switch.

Meter range selector.
On the "OUTPUT CURRENT" position of the RANGE SELECTOR the meter indicates the output current with a F.S.D. of 1A (Scale reading x 1A).
On the "DIFFERENTIAL" positions of the RANGE SELECTOR the meter indicates the difference between the unknown and the reference voltages applied to the differential voltmeter with a F.S.D. corresponding to the setting of the RANGE SELECTOR providing the MULTIPLIER is in the "x 1" or "x 0.1" positions.

MULTIPLIER
3 - position
Rotary Switch

In the "x 1" and "x 0.1" positions of the MULTIPLIER the reference voltage applied to the differential voltmeter is respectively unattenuated and attenuated by a factor of 10. In the "x 10" position of the Multiplier the voltage to be measured is attenuated by a factor of 10, enabling voltages up to 1,000V to be measured.
However, in the "x 10" position of the MULTIPLIER, the sensitivity of the meter DIFFERENTIAL ranges is

affected as follows: -

RANGE SELECTOR SETTING	VOLTAGE at INPUT for F.S.D.
1mV	100mV
10mV	190mV
100mV	1.09 V
1 V	10.9 V
10 V	109.0 V
100 V	1090.0 V

INPUT
Terminals

Provide connection for measurement of unknown D.C. voltages:

Red - Positive
Black - Negative

SET ZERO

These controls, comprising the O/C potentiometer and the S/C potentiometer and push-button switch provide facilities for setting the differential voltmeter zero to compensate for long-term drift.

On the back panel of the instrument are located:

the MAINS INPUT socket and the INPUT VOLTAGE SELECTOR
the MAINS FUSE - 2A for 110V supply range
1A for 220V supply range
anti-surge
the OUTPUT FUSE - 1A
RECORDER OUTPUT Provide connection for a pen recorder:

Red - Positive
Black - Negative

The output at these terminals is 1 - 0 - 1V, corresponding to F.S.D. on the panel meter.

OPERATION AS A POWER SUPPLY

Switch on the MAINS toggle switch.

Allow a period of at least 30 minutes for the instrument to reach stable operating conditions. After this period thermal equilibrium of the instrument (and in particular

that of the temperature controlled oven) will be established and the instrument will operate within the limits of accuracy quoted in the specification.

Make appropriate connections to the OUTPUT and FEEDBACK terminals as detailed above.

Using the OUTPUT CONTROLS, select the required output voltage.

Set the RANGE SELECTOR switch to the "OUTPUT CURRENT" position to monitor output current.

Switch on the OUTPUT toggle switch.

For a temporary switch-off, switch off the OUTPUT toggle switch only to leave the instrument in a "stand-by" position and thus eliminate the "warm-up" period when the output voltage is again required.

The output current of the VR2 is limited to 600mA. Reducing the resistance of the load, or increasing the output voltage beyond the value corresponding to this current will cause the output current to be reduced until, with a short circuit across the OUTPUT terminals, the output current will be 150mA.

OPERATION AS A DIFFERENTIAL VOLTMETER

Switch on the MAINS toggle switch and allow the 30 minute "warm-up" period to elapse.

With no connection to the INPUT terminals and with the RANGE SELECTOR switch set to the "1mV" position, adjust the SET ZERO controls:

1. Holding the S/C push-button depressed adjust the S/C potentiometer to obtain a zero reading on the meter (i.e. centre-scale).

2. Release the push-button and adjust the O/C potentiometer to obtain a zero reading on the meter.

NOTE: Pressing the S/C push-button introduces a short circuit across the input to the differential voltmeter amplifier and is not equivalent to shorting the INPUT terminals.

Set the RANGE SELECTOR switch to the "100V" position.

Set the MULTIPLIER switch to the "x 1" or the "x 0.1" position, unless the voltage to the measured is possibly greater than 100V, when the "x 10" position should be used.

Set the OUTPUT CONTROLS to 00.000.

NOTE: The OUTPUT toggle switch may be left in either the "ON" or "OFF" positions.

Apply the voltage to be measured to the INPUT terminals when an approximate indication of its value will be given by the meter.

The meter deflection should be towards the right-hand side of the scale. If the deflection is towards the left-hand side of the input polarity is incorrect and the connections to the INPUT terminals should be reversed.

The RANGE SELECTOR switch may now be turned to a more sensitive setting if required.

With the MULTIPLIER switch in the "x 1" or the "x 0.1" position the F.S.D. of the meter corresponds to the setting of the RANGE SELECTOR switch.

With the MULTIPLIER switch in the "x 10" position, the meter has a reduced sensitivity:

RANGE SELECTOR SETTING	VOLTAGE AT INPUT FOR F.S.D.
10V	109.0V
100V	1090.0V

Using the approximate indication of the input voltage as a guide, set the OUTPUT CONTROLS to reduce the indication on the meter to zero.

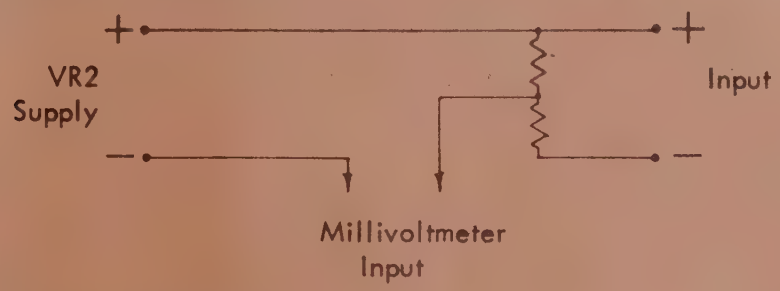
Set the RANGE SELECTOR switch to successively more sensitive ranges and re-adjust the OUTPUT CONTROLS on each range to obtain an accurate null indication.

A meter deflection to the right indicates that the voltage being measured is higher than the reference voltage corresponding to the OUTPUT CONTROLS setting, while a meter deflection to the left indicates the reverse condition.

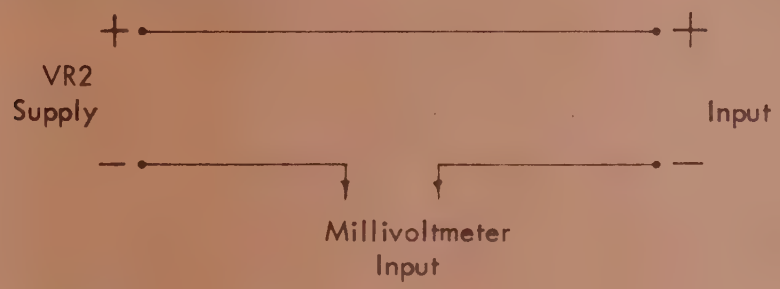
Once an accurate null indication is obtained, the measured voltage is given by the reading indicated on the dials of the OUTPUT CONTROLS multiplied by the MULTIPLIER switch setting indication.

Fig.1 INPUT AND OUTPUT CONNECTIONS

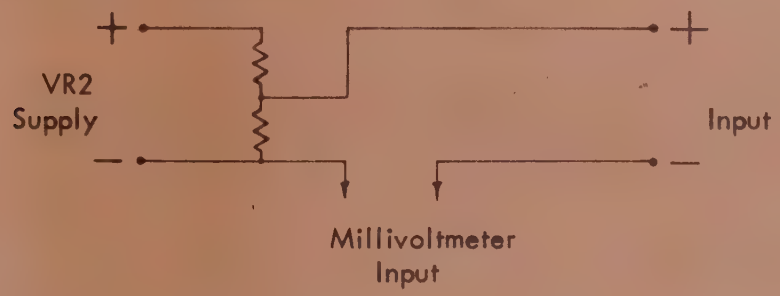
MULTIPLIER "x10" POSITION



MULTIPLIER "x1" POSITION



MULTIPLIER "x0.1" POSITION



The diagrams illustrate the internal connections between the OUTPUT and INPUT terminals of the VR2 for the various multiplier switch positions.

Care should be taken to avoid earth connections to the source of the voltage to be measured and to the VR2 at points which are not otherwise directly connected. In general a single earth point should be used and the VR2 supply left in the floating condition (i.e. with no direct connection between the OUTPUT terminals and the earth terminal).

Section 5. SERVICING - SETTING-UP PROCEDURE

The Theory of Operation and Circuit Description in Section 3 of this manual, together with the accompanying circuit diagrams, should enable the service engineer to readily locate and remedy any fault occurring in the VR2.

The service facilities of Farnell Instruments Limited are, of course, available to owners of the VR2.

If any replacement of components in the power supply section of the instrument is effected, the following checking procedure should be adopted:

1. Adjust the "set-on-test" resistor, SOT1, in parallel with R18 until the voltage across R19 becomes 1.75 $^{+}_{-}$0.03V. This ensures correct bias conditions for the reference element Z4.

2. Check that the voltage across C103 is 20.0V to ensure that the operation of the voltage stabiliser formed by VT1, VT3 and VT4 is satisfactory.

3. With the OUTPUT CONTROLS set to 00.000, adjust the potentiometer T101, located on the side panel, for zero voltage ($^{+}_{-}$0.1mV) at the OUTPUT terminals.

4. With the OUTPUT CONTROLS set to 90.000, load the unit to 600mA (as measured on an external meter). Set the RANGE SELECTOR switch to the "OUTPUT CURRENT" position and adjust the potentiometer T104, located on the side panel, to obtain a reading on the VR2 meter scale of .6.

5. With the OUTPUT CONTROLS still set to 90.000, and the unit loaded to 600mA, set the potentiometer T102, located on the side panel, to the position at which the output current just begins to fall from 600mA.

6. Maintaining the same instrument settings, short circuit the output terminals and adjust the potentiometer T103, located on the side panel, to obtain a reading on the VR2 meterscale of .15 (i.e. a short-circuit current of 150mA.).

7. A particular combination of padder resistors in the precision divider block must be selected and connected to compensate for tolerance in the reference zener diode voltage.

   Proceed as follows:
   (a) Set SOT2 at zero resistance
   (b) Connect a lead from the junction of R22 and T105 (i.e. tag 26 or tag 28) to the connection marked "a" on the precision divider block, thus by-passing

the padder resistors.

(c) Set the OUTPUT CONTROLS to 100.000V.

(d) With the MAINS switch on, the OUTPUT switch on and no load connected to the instrument, measure the voltage appearing at the OUTPUT terminals to an accuracy of 0.01%.

(e) Substract 100.00V from the measured value of the output voltage and multiply the difference (in volts) by 10 to obtain the value (in ohms) of the required combination of padder resistors.

(f) The padder resistors in the precision divider block have values of 54 ohms, 68 ohms and 82 ohms and are connected between the terminals on the block marked a - b, c - e and c - d respectively.
The values of the various possible series and parallel combinations of the three padder resistors are listed in Table 1 overleaf, of this manual.

(g) Select the combination of padder resistors which has the nearest lower value to that found in step (e) and make the appropriate connections to terminals a, b, c, d, e and tag 28.

8. Final adjustment of the output voltage is made as follows:

Repeat the procedure detailed in steps 7(c) and 7(d) and select a value of resistor SOT 2 as a coarse adjustment and adjust the potentiometer T105, located on the side panel, as a fine adjustment to obtain an output voltage of 100.00V ±0.01%.

TABLE 1

PRECISION DIVIDER BLOCK PADDER RESISTOR COMBINATIONS

Resistor R14

A	- 54 ohms	a - b
B	- 68 ohms	c - e
C	- 82 ohms	c - d

Value of combination (ohms)	Combination	Connection: Connect together:	Connection: Connect tag 28 to:
30	A//B	a and c	b and e
32.5	A//C	a and d	b and c
37	B//C	a and c	d and e
54	A	-	b
68	B	a and c	e
82	C	a and c	d
91	A + B//C	b and c	d and e
100.5	B + A//C	a and d b and c	e
112	C + A//B	a and c b and e	d
122	A + B	b and c	e
136	A + C	b and c	d
150	B + C	a and e	d
204	A + B + C	b and e	d

NOTE: $A//B = \frac{A \times B}{A + B}$

If any replacement of components in the differential voltmeter section of the instrument is effected, the following checking procedure should be adopted:

1. With no connection to the INPUT terminals and with the RANGE SELECTOR switch set to the "1mV" position, check the SET ZERO controls.

2. With the S/C push button depressed, if a zero meter indication cannot be obtained within the traverse of the S/C potentiometer, the "select - on - test" resistors, SOT R37A and SOT R38A, (in parallel with R17A and R22A respectively) must be re-selected.
   Set the S/C Potentiometer to mid-traverse and press the S/C push-button. A meter deflection to the right indicates that a ~~smaller~~ LARGER effective value of R17A is required, while a meter deflection to the left indicates that a ~~smaller~~ LARGER effective value of R22A is required.
   Select a value of R37A or of R38A from the range; 1.2M, 470K, 220K, 100K, 22K ±10% which enables a zero meter indication to be obtained within the traverse of the S/C potentiometer.
   NOTE: After changing a resistor, allow sufficient time (approximately 5 minutes) for the heat, due to soldering, to dissipate before assessing its effects.

3. If a zero meter indication cannot be obtained within the traverse of the O/C potentiometer, the "select - on - test" resistor, SOT R36A, (in parallel with R11A) must be re-selected.
   Set the O/C potentiometer to mid-traverse.
   Select a value of R36A from the range of 10% preferred values between 22K and 1.5M which gives the meter indication nearest zero making allowance for heat due to soldering (see NOTE above).

4. Set the RANGE SELECTOR switch to the "100V" position and the MULTIPLIER switch to the "x 1 " position.
   Short the INPUT terminals and set the OUTPUT CONTROLS to 100.000V.
   Adjust T1A to obtain a potential at tag 76 of -0.5mV relative to tag 87, as measured with a differential voltmeter to avoid loading effects.

5. Set the RANGE SELECTOR switch to the "1V" position.
   Set the OUTPUT CONTROLS to 1.000V and adjust T2A to obtain a full-scale meter deflection (which will be to the left).

   NOTE: The method outlined in steps 4 and 5 uses the power supply section of the VR2 itself to provide the calibrating voltage for the differential voltmeter section. As an alternative, an external calibrating voltage supply may be connected to the INPUT terminals and the OUTPUT CONTROLS set to 00.000, in which case tag 76 will be positive with respect to tag 87 in step 4 and the meter deflection will be to the right in step 5.

6. To set up the MULTIPLIER x 10 attenuator:
   Set the MULTIPLIER switch to the "x 10" position.
   Set the OUTPUT CONTROLS to 10.000V.
   Apply 100.00V ($\pm$0.03%) from an external supply to the INPUT terminals.
   Setting the RANGE SELECTOR switch to successively more sensitive ranges, adjust T3A, located on the side panel, to obtain an accurate null indication.

USED ON	LOCATION	COMPONENT NUMBER	QUANTITY	VALUE	TOLERANCE	MANUFACTURER	MANUFACTURER'S TYPE No	MANUFACTURER'S RATING	OPERATIONAL RATING (MAX)	REMARKS
	CB1	R2	1	10 ohm	5%	Electrosil	TR5			B1440
	"	R3	1	1k ohm	10%	Dubilier	BTA			
	"	R4	1	470 ohm	10%	"	BTA			
	"	R5	1	2.7k ohm	10%	ERG	58 AV			
	"	R6	1	470 ohm	10%	ERG	58 AV			
	"	R9	1	1.5k ohm	5%	Electrosil	TR 5			
	"	R10	1	120 ohm	5%	Electrosil	TR 5			
	"	R11	1	8.2k ohm	5%	Electrosil	TR 5			
	"	R14	1	4.7k ohm	5%	Electrosil	TR 5			
	"	R15	1	12k ohm	1%	Welwyn	M81/4051			
	"	R16	1	9.1k ohm	1%	Welwyn	M81/4051			
	"	R17	1	5.6k ohm	5%	Electrosil	TR 5			
	"	R18	1	560 ohm	1%	Welwyn	M81/4051			
	"	R19	1	100 ohm	1%	Welwyn	M81/4051			
	"	R20	1	33k ohm	5%	Electrosil	TR 5			
	"	R21	1	33k ohm	5%	Electrosil	TR 5			
	"	R22	1	56k ohm	5%	Electrosil	TR 5			
	"	R23	1	22k ohm	5%	Electrosil	TR 5			
	"	R24	1	22k ohm	5%	Electrosil	TR 5			
	"	R25	1	22k ohm	5%	Electrosil	TR 5			
	"	R26	1	8.2k ohm	5%	Electrosil	TR 5			
	"	R27	1	1k ohm	5%	Electrosil	TR 5			
	"	R28	1	5.6k ohm	5%	Electrosil	TR 5			
	"	R29	1	1·5K ohm	5%	Electrosil	TR 5			
	"	R34	1	1 ohm	10%	CGS	VPF4			
	"	R40	1	0.5 ohm	10%	CGS	VPF4			
	"	R42	1	10k ohm	5%	Electrosil	TR 5			
	"	R43	1	4.7k ohm	5%	Electrosil	TR 5			
	"	R101	1	2.7k ohm	5%	Electrosil	TR 5			
	"	R102	1	1.2k ohm	5%	Electrosil	TR 5			
	"	R103	1	390 ohm	5%	Electrosil	TR 5			
	"	R104	1	470 ohm	5%	Electrosil	TR 5			
	"	R105	1	470 ohm	5%	Electrosil	TR 5			
		SOT1			5%	Welwyn M81 from 1k, 1.2k, 1.5k, 1.8k, 2.2k.				
		SOT2			5%	Painton MVIA from range 2.2, 2.7, 6.3, 9.9, 4.7, 6.8, 10, 12, 15, 18, 22, 27 ohm.				

LOCATION	COMPONENT NUMBER	QUANTITY	VALUE	TOLERANCE	MANUFACTURER	MANUFACTURER'S TYPE No	MANUFACTURER'S RATING	OPERATIONAL RATING (MAX)	REMARKS
CB1	C101	1	10uF	6V	T.C.C.	CE58PVC			
"	C102	1	100uF	25V	T.C.C.	CE133C			
"	C103	1	100uF	25V	T.C.C.	CE133C			
"	C104	1	200uF	6V	T.C.C.	CE513A			
"	C105	1	0.1uF	160V	Wima	TFF			
"	VT1	1			R.C.A.	2N3053			
"	VT3	1			SGS-F	U15025			
"	VT4	1			SGS-F	U15025			
"	VT7	1			SGS-F	U15025			
"	VT8	1			SGS-F	U15025			
"	VT9	1			S.T.C.	BCY.43			
"	VT10	1			S.T.C.	BCY.43			
"	VT11	1			S.T.C.	BCY.43			
"	VT12	1			R.C.A.	2N3440			
"	Z3	1			Mullard	OAZ244			
"	Z6	1			Brush/IB	ZF15/MZ15T5			
"	D1	1			Texas	In659			
"	D3	1			Texas	In659			
CB2	R1	1	0.5 ohm	10%	CGS	VPF4			A1443
"	R30	1	3.3k ohm	5%	Electrosil	TR 5			
"	R32	1	3.3k ohm	5%	Electrosil	TR 5			
"	R33	1	100 ohm	5%	Electrosil	TR 5			
"	R35	1	82k ohm	5%	Electrosil	TR 5			
"	R36	1	4.7k ohm	5%	Painton	MVIA			
"	R37	1	4.7k ohm	5%	Painton	MVIA			
"	R38	1	6.8k ohm	5%	Electrosil	TR 5			
"	R39	1	47k ohm	[illegible]	Electrosil	TR 5			
"	R108	1	6.[illegible] ohm	5%	Dubilier	BTT			
"	C1	1	0.22uF	400V	Wima	TFM			
"	C7	1	1000pF	400V	Wima	TFF			
"	C6	1	100MF	25V	T.C.C.	CE 133C			
"	VT14	1			R.C.A.	2N3053			
"	VT16	1			SGS-F	C407			
"	VT17	1			SGS-F	C407			
"	Z5	1			I.R.	MZ15T5			
"	D2	1			Texas	13923			

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FARNELL INSTRUMENTS LTD, WETHERBY, YORKS

TITLE :— CIRCUIT DIAGRAM KEY VR2

DRAWING No. C1500 K

SHEET 1 OF 4 SHEETS

H.H.L.: 2595 64

USED ON	LOCATION	COMPONENT NUMBER	QUANTITY	VALUE	TOLERANCE	MANUFACTURER	MANUFACTURER'S TYPE No	MANUFACTURER'S RATING	OPERATIONAL RATING (MAX)	REMARKS
	CB2	BR1	4			Ferranti	ZS74			
	CB3	R7	1	330 ohm		ERC	58AV			A1446
	"	R8	1	1.2k ohm		ERC	58AV			
	"	C5	1	100uF	150V	T.C.C.	CWE125FC			
	"	BR2	4	200V,	200mA	Texan et alia	1S923 et alia			
	"	Z1	1			I.R.	MZ18T5			
	"	Z2	1			I.R.	MZ18T5			
	"	N1	1	(red)		Arcolectric	SL162			
	"	M1	1	100uA-0-100uA		Sangamo Weston	S156			
	"	S1	1			N.S.F.	8370K7/CHP			
	"	S7	1			N.S.F.	8373K7/CHP			
	"	R109	1	1k ohm		Electrosil	TR 5			
	"	R110	1	1k ohm		Electrosil	TR 5			
	"	C8	1	·47uF	125V	Wima	Tropyfol-M			
	"	VT15	1			R.C.A.	2N3054			
	"	VT18	1			R.C.A.	2N3054			
	"	VT19	1			R.C.A.	2N3054			
	"	C2	1	1000uF	300V	T.C.C.	CE553k			
	"	VT58	1			SGS-F	U3164/1			
	"	Z4	1			Transitron	1N944			
	"	T101	1	50k ohm		Plessey	M			
	"	T102	1	5k ohm		Plessey	M			
	"	T103	1	1k ohm		Plessey	M			
	"	T104	1	5 ohm		Plessey	M			
	"	T105	1	250 ohm		Plessey				
	"	C4	1	1200uF	150V	T.C.C.	TCE552F			
	"	S2c+d	1			N.S.F.				A98
	"	C3	1	10uF	250V	Wima	MKB 1			
	"	TFR	1			Westool	BTX3078A5P5			
	"	FLT	1	0.22uF	630V	Wima	Durolit			
	"	F1	1	500mA		Belling Lee	F297			
	"	F2	1	750mA		Belling Lee	F297			
	CB4	R76	1	100 ohm	10%	Dublier	BTT			
	"	R77	1	1 ohm	5%	CGS	YPF4			
	"	R78	1	2.7Kohm	5%	CGS	58 AV			
	"	R79	1	680 ohm	10%	CGS	BTT			

LOCATION	COMPONENT NUMBER	QUANTITY	VALUE	TOLERANCE	MANUFACTURER	MANUFACTURER'S TYPE No	MANUFACTURER'S RATING	OPERATIONAL RATING (MAX)	REMARKS
CB4	C18	1	1000uF	25V	CGS	CT4230			
"	C19	1	40uF	150V	Hunts	JF157T			
"	C20	1	0.47uF	125V	Wima	Tropyfol-M			
"	MR6	4			Texas et alia	1S132 et alia			
"	MR7	4			Ferranti	ZS72			

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FARNELL INSTRUMENTS LTD, WETHERBY, YORKS.

TITLE :— CIRCUIT DIAGRAM KEY VR2

DRAWING No. C1500/K.

SHEET 2 OF 4 SHEETS

H.M.L. 2595.64

USED ON	LOCATION	COMPONENT NUMBER	QUANTITY	VALUE	TOLERANCE	MANUFACTURER	MANUFACTURER'S TYPE No	MANUFACTURER'S RATING	OPERATIONAL RATING (MAX.)	REMARKS	LOCATION	COMPONENT NUMBER	QUANTITY	VALUE	TOLERANCE	MANUFACTURER	MANUFACTURER'S TYPE No	MANUFACTURER'S RATING	OPERATIONAL RATING (MAX.)	REMARKS
	CB1	2 & 3																		
		R1B	1	1.8k ohm	10%	Dubilier	BTT													
	6	R2B	1	10k ohm	10%	Dubilier	BTT													
	7	R3B	1	5.6k ohm	10%	Dubilier	BTT													
	8	R4B	1	1.2Mohm	10%	Dubilier	BTT													
	9	R5B or RS30		20-30 ohm		Eureka Wire	26 SWG			26 SWG Eureka										
	10																			
	11																			
	12	VT1B	1			Mullard	OC204													
	13	VT2B	1			Mullard	OC204													
	14	VT3B	1			Mullard	OC204													
	15	VT4B	1			Mullard	OC204													
	16																			
	17																			
	18	T1B	1	1kn Lin.	20%	Plessey Dealer	MP 404/8/0285/001													
	19																			
	20																			
	21	D1B				Texas	Zs72													
	22																			
	23																			
	24	Z1B	1	18v.	10%	I.R.C.	MZ18T10													
	25																			
	26	TH1B	1			S.T.C.	G25													
	27																			
	28																			
	29																			

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FARNELL INSTRUMENTS LTD, WETHERBY, YORKS.

TITLE :— CIRCUIT DIAGRAM KEY VR2

DRAWING No. C1500 K

SHEET 3 OF 4 SHEETS

USED ON	LOCATION	COMPONENT NUMBER	QUANTITY	VALUE	TOLERANCE	MANUFACTURER	MANUFACTURER'S TYPE No	MANUFACTURER'S RATING	OPERATIONAL RATING (MAX)	REMARKS
		R1A	1	50K ohm	1%	Welwyn	4016T.C.	100 ppm.		
		R2A	1	900K ohm	1%	Welwyn	4015T.C.	100 ppm.		
		R3A	1	9Mohm	1%	Welwyn	4016T.C.	150 ppm.		
		R4A	1	1Mohm	1%	Welwyn	4015T.C.	100 ppm.		
		R5A	1	12K ohm	1%	Welwyn	4015T.C.	100 ppm.		
		R6A	1	10.1K ohm	1%	Welwyn	4015T.C.	100 ppm.		
		R7A	1	1 Kohm	1%	Welwyn	4015T.C.	100 ppm.		
		R8A	1	680 ohm	10%	Dubilier	B.T.A.			
		R9A	1	10K ohm	5%	Electrosil	TR 5			
		R10A	1	100K ohm	1%	Erie	N6A			
		R11A	1	470K ohm	5%	Electrosil	TR 5			
		R12A	1	22K ohm	5%	Electrosil	TR 5			
		R13A	1	100K ohm	1%	Erie	N6A			
		R14A	1	1M ohm		Erie	N6A			
		R15A	1	4.7K ohm	5%	Electrosil	TR 5			
		R16A	1	22K ohm	5%	Electrosil	TR 5			
		R17A	1	270K	5%	Electrosil	TR 5			
		R18A	1	4·7Kohm	5%	Electrosil	TR 5			
		R19A	1	18K ohm	5%	Electrosil	TR 5			
		R20A	1	18K ohm	5%	Electrosil	TR 5			
		R21A	1	22K ohm	5%	Electrosil	TR 5			
		R22A	1	270K ohm	5%	Electrosil	TR 5			
		R23A	1	10 ohm	1%	Erie	N6A			
		R24A	1	4.7K ohm	5%	Electrosil	TR 5			
		R25A	1	10K ohm	5%	Electrosil	TR 5			
		R26A	1	100 ohm	5%	Electrosil	TR 5;			
		R27A	1	1k ohm	5%	Electrosil	TR 5			
		R28A	1	9k ohm	1%	Erie	NGA			
		R29A	1	18K ohm	1%	Erie	NGA			
		R30A	1	10K ohm	5%	Electrosil	TR 5			
		R31A	1	220 ohm	5%	Electrosil	TR 5			
		R32A	1	9Mohm	1%	Welwyn	4016T.C.	150 ppm.		
		R33A	1	950K ohm	1%	Welwyn	4015T.C.	100 ppm.		
		C1A	1	100uF	50V	Sprague	HD1			
		C2A	1	1uF	125v	Wima	TFM			
		C3A	1	0·01uF	125v	Wima	TFF			
		C4A	1	100pF	400v	Wima	TFF			
		R34A	1	9kn		Muirhead	K70DKU			

LOCATION	COMPONENT NUMBER	QUANTITY	VALUE	TOLERANCE	MANUFACTURER	MANUFACTURER'S TYPE No	MANUFACTURER'S RATING	OPERATIONAL RATING (MAX)	REMARKS
	R35A	1	1kn		Muirhead	K70AKU			
	P1A	1	5k ohm		Plessey	L20% Lin			Plain Nuts 9/16" shaft.
	P2A	1	50k ohm		Plessey	L20% Lin			
	T1A	1	56k ohm		Plessey Dealer	MP20% Lin.			
	T2A	1	5.6k ohm		Plessey Dealer	MP20% Lin.			
	T3A	1	100k ohm		Plessey Dealer	MP20% Lin.			Slotted Spindle 5/18" shaft
	D1A	1			Texas	1S923			
	DZA	1			Texas	G129			
	Z1A	1			I-R	MZ1OT5			
	Z2A	1			I-R	MZ1OT5			
	Z3A	1			Mullard	OAZ240			
	Z4A	1			S.T. + C	ZF6.2			
(NPN)	VT1A	1			SGS Fairchild	U3164/1			
(NPN)	VT2A	1							
(PNP)	VT3A	1			SGS Fairchild	U15025			
(NPN)	VT4A	1			S.T. + C	BCY43			
(PNP)	VT5A	1			SGS Fairchild	U15025			
(NPN)	VT6A	1			S.T. + C.	BCY43			
(NPN)	VT7A	1			S.T. + C	BCY43			
	$S13_A$	1			Secme from Waycom	W.P.S.1			
	S12	1			N.S.F.	4p 7w Jk			
	S11	1			N.S.F.	3p 3w MHLC			Indexing as for JKSpindle length from mounting fa -¾" threaded length - "
	$Z5_A$								
	R36A	1			Dubilier	BTT			
	R37A	1			Dubilier	BTT			
	R38A	1			Dubilier	BTT			
	R39A	1	120KΩ	5%	Electrosil	TR 5			
	R40A	1	120KΩ	5%	Electrosil	TR 5			

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FARNELL INSTRUMENTS LTD, WETHERBY, YORKS.

TITLE :— CIRCUIT DIAGRAM KEY VR2

DRAWING No. C1500/K

SHEET 4 OF 4 SHEETS

H.N.-L2: 2595/64

MP MASTER
MA23389